

which corresponds to slightly more than half the bandgap of silicon. In NGSPICE modified to simulate SiC JFETs, this parameter is changed to a value of 1.6, corresponding to slightly more than half the bandgap of SiC. The second modification consists of changing the temperature dependence of MOSFET transconductance and saturation parameters. The unmodified NGSPICE source code implements a  $T^{-1.5}$  temperature dependence for these parameters. In order to mimic the temperature behavior of ex-

perimental SiC JFETs, a  $T^{-1.3}$  temperature dependence must be implemented in the NGSPICE source code.

Following these two simple modifications, the "Level 1" MOSFET model of the NGSPICE circuit simulation program reasonably approximates the measured high-temperature behavior of experimental SiC JFETs properly operated with zero or reverse bias applied to the gate terminal. Modification of additional silicon parameters in the NGSPICE source code was not neces-

sary to model experimental SiC JFET current-voltage performance across the entire temperature range from 25 to 500 °C.

*This work was done by Philip G. Neudeck of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18342-1.*

## TDR Using Autocorrelation and Varying-Duration Pulses

### Signal-to-noise ratios may be increased.

*John F. Kennedy Space Center, Florida*

In an alternative to a prior technique of time-domain-reflectometry (TDR) in which very short excitation pulses are used, the pulses have very short rise and fall times and the pulse duration is varied continuously between a minimum and a maximum value. In both the present and prior techniques, the basic idea is to (1) measure the times between the generation of excitation pulses and the reception of reflections of the pulses as indications of the locations of one or more defects along a cable and (2) measure the amplitudes of the reflections as indication of the magnitudes of the defects.

In general, an excitation pulse has a duration  $T$ . Each leading and trailing

edge of an excitation pulse generates a reflection from a defect, so that a unique pair of reflections is associated with each defect. In the present alternative technique, the processing of the measured reflection signal includes computation of the autocorrelation function

$$R(\tau) \equiv \int x(t)x(t-\tau)dt$$

where  $t$  is time,  $x(t)$  is the measured reflection signal at time  $t$ , and  $\tau$  is the correlation interval. The integration is performed over a measurement time interval short enough to enable identification and location of a defect within the corresponding spatial interval along the cable. Typically, where there is a defect,  $R(\tau)$  exhibits a negative peak having maximum magnitude for  $\tau$  in the vicinity of  $T$ . This peak

can be used as a means of identifying a leading-edge/trailing-edge reflection pair.

For a given spatial interval, measurements are made and  $R(\tau)$  computed, as described above, for pulse durations  $T$  ranging from the minimum to the maximum value. The advantage of doing this is that the effective signal-to-noise ratio may be significantly increased over that attainable by use of a fixed pulse duration  $T$ .

*This work was done by Angel Lucena, Pam Mullinex, PoTien Huang, and Josephine Santiago of Kennedy Space Center and Pedro Medelius, Carlos Mata, Carlos Zavala, and John Lane of ASRC Aerospace Corp. Further information is contained in a TSP (see page 1).*  
*KSC-12856*

## Update on Development of SiC Multi-Chip Power Modules

### Modules and a modular power system have been built and tested.

*John H. Glenn Research Center, Cleveland, Ohio*

Progress has been made in a continuing effort to develop multi-chip power modules (SiC MCPMs). This effort at an earlier stage was reported in "SiC Multi-Chip Power Modules as Power-System Building Blocks" (LEW-18008-1), *NASA Tech Briefs*, Vol. 31, No. 2 (February 2007), page 28.

The following unavoidably lengthy recapitulation of information from the cited prior article is prerequisite to a meaningful summary of the progress made since then:

- SiC MCPMs are, more specifically, electronic power-supply modules containing multiple silicon carbide power integrated-circuit chips and silicon-on-insulator

(SOI) control integrated-circuit chips. SiC MCPMs are being developed as building blocks of advanced expandable, reconfigurable, fault-tolerant power-supply systems. Exploiting the ability of SiC semiconductor devices to operate at temperatures, breakdown voltages, and current densities significantly greater than those of conventional Si devices, the designs of SiC MCPMs and of systems comprising multiple SiC MCPMs are expected to afford a greater degree of miniaturization through stacking of modules with reduced requirements for heat sinking.

- The stacked SiC MCPMs in a given sys-

tem can be electrically connected in series, parallel, or a series/parallel combination to increase the overall power-handling capability of the system. In addition to power connections, the modules have communication connections. The SOI controllers in the modules communicate with each other as nodes of a decentralized control network, in which no single controller exerts overall command of the system. Control functions effected via the network include synchronization of switching of power devices and rapid reconfiguration of power connections to

enable the power system to continue to supply power to a load in the event of failure of one of the modules.

- In addition to serving as building blocks of reliable power-supply systems, SiC MCPMs could be augmented with external control circuitry to make them perform additional power-handling functions as needed for specific applications. Because identical SiC MCPM building blocks could be utilized in such a variety of ways, the cost and difficulty of designing new, highly reliable power systems would be reduced considerably. This concludes the information from the cited prior article.

The main activity since the previously reported stage of development was the design, fabrication, and testing a 120-

VDC-to-28-VDC modular power-converter system composed of eight SiC MCPMs in a 4 (parallel)-by-2 (series) matrix configuration, with normally-off controllable power switches. The SiC MCPM power modules include closed-loop control subsystems and are capable of operating at high power density or high temperature. The system was tested under various configurations, load conditions, load-transient conditions, and failure-recovery conditions.

Planned future work includes refinement of the demonstrated modular system concept and development of a new converter hardware topology that would enable sharing of currents without the need for communication among modules. Toward these ends, it is also

planned to develop a new converter control algorithm that would provide for improved sharing of current and power under all conditions, and to implement advanced packaging concepts that would enable operation at higher power density.

*This work was done by Alexander Lostetter, Edgar Cilio, Gavin Mitchell, and Roberto Schupbach of Arkansas Power Electronics International, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18341-1.*

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## Radio Ranging System for Guidance of Approaching Spacecraft

*Lyndon B. Johnson Space Center, Houston, Texas*

A radio communication and ranging system has been proposed for determining the relative position and orientations of two approaching spacecraft to provide guidance for docking maneuvers. On Earth, the system could be used similarly for guiding approaching aircraft and for automated positioning of large, heavy objects. In principle, the

basic idea is to (1) measure distances between radio transceivers on the two spacecraft and (2) compute the relative position and orientations from the measured distances.

Half-duplex communication links would be established between transceivers on the two spacecraft, and pulses having durations of the order of a nanosecond

would be exchanged. The distances would be determined by the pulse-time-of-flight method. Data signals could be transmitted in addition to ranging pulses.

*This work was done by Vikram Manikonda and Eric van Doorn of Intelligent Automation, Inc. for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-23474-1*

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## Electromagnetically Clean Solar Arrays

**Cells are laminated with shielding, narrow-current-loop wiring, and structural supports.**

*John H. Glenn Research Center, Cleveland, Ohio*

The term “electromagnetically clean solar array” (“EMCSA”) refers to a panel that contains a planar array of solar photovoltaic cells and that, in comparison with a functionally equivalent solar-array panel of a type heretofore used on spacecraft, (1) exhibits less electromagnetic interference to and from other nearby electrical and electronic equipment and (2) can be manufactured at lower cost. The reduction of electromagnetic interference is effected through a combination of (1) electrically conductive, electrically grounded shielding and (2) reduction of areas of current loops (in order to reduce magnetic moments). The reduction of cost is effected by designing the array to be fabricated as a more nearly unitary structure, using fewer components and fewer process steps. Although EMSCAs

were conceived primarily for use on spacecraft, they are also potentially advantageous for terrestrial applications in which there are requirements to limit electromagnetic interference.

In a conventional solar panel of the type meant to be supplanted by an EMCSA panel, the wiring is normally located on the back side, separated from the cells, thereby giving rise to current loops having significant areas and, consequently, significant magnetic moments. Current-loop geometries are chosen in an effort to balance opposing magnetic moments to limit far-field magnetic interactions, but the relatively large distances separating current loops makes full cancellation of magnetic fields problematic. The panel is assembled from bare photovoltaic cells by means of multiple sensitive process steps that con-

tribute significantly to cost, especially if electromagnetic cleanliness is desired. The steps include applying a cover glass and electrical-interconnection tabs to each cell to create a cell-interconnect-cell (CIC) subassembly, connecting the CIC subassemblies into strings of series-connected cells, laying down and adhesively bonding the strings onto a panel structure that has been made in a separate multi-step process, and mounting the wiring on the back of the panel. Each step increases the potential for occurrence of latent defects, loss of process control, and attrition of components.

An EMCSA panel includes an integral cover made from a transparent silicone material. The silicone cover supplants the individual cover glasses on the cells and serves as an additional unitary structural support that offers the advantage, relative